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REGULATORY POLICY FOR ADVANCED NUCLEAR REACTORS

REPORT

PREPARED BY THE

SUBCOMMITTEE ON

ENERGY RESEARCH AND PRODUCTION

TRANSMITTED TO THE

COMMITTEE ON SCIENCE AND TECHNOLOGY HOUSE OF REPRESENTATIVES

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LETTER OF TRANSMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC, June 1986.

Hon. DON FUQUA,
Chairman, Committee on Science and Technology,
House of Representatives, Washington, DC.

DEAR MR. CHAIRMAN: The attached report contains the Subcommittee's findings and recommendations on Regulatory Policy for Advanced Nuclear Reactors. The report includes excerpts from our hearing transcripts.

The Subcommittee has made four recommendations covering; definition, performance criteria, enhanced safety and standardized designs. We believe the timely adaptation of these recommendations will lead to deployment of safer nuclear reactors in the future.

I hope you will submit these recommendations to the Committee on Interior and Insular Affairs for considerati m and appropriate action.

Sincerely,

MARILYN LLOYD,
Chairman, Subcommittee on Energy Research and Production.

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REGULATORY POLICY FOR ADVANCED NUCLEAR REACTORS

Energy Research and Production
Subcommittee Report

BACKGROUND

The Energy Reorganization Act of 1974 established the Energy Research and Development Administration (ERDA) to promote the efficient and reliable use of energy, and the Nuclear Regulatory Commission (NRC) to maintain licensing and regulatory authority over nuclear facilities and activities.

There are several different kinds of reactors, generally referred to by the choice of coolant and moderator, e.g., the light water reactors used almost exclusively by U.S. utility companies for electric power generation. During the 1960's and 1970's, the major portion of U.S. enery related research funds were spent on the "fast reactor" which employs a liquid metal coolant. The funds available for advancements in the development of other kinds of reactors was, therefore, limited even though there are no commercial fast reactors in the U.S. The budget for fast reactor development was greatly reduced by the termination of the Clinch River Breeder Reactor Project. In the past few years, there has been renewed interest 1) in the Modular High Temperature Gas-Cooled Reactor (MHTGR) which has passive safety features, 2) in the Swedish designed, Process Inherent Ultimately Safe Reactor (PIUS) concept, and 3) in certain innovative liquid metal and advanced light water reactor concepts which are under consideration.

Today's light water reactors consisting of pressurized water reactors and boiling water reactors used for the generation of electric power in the U.S. are the result of 30 years of evolutionary design. Today's design modifications appear to be more the result of piecemeal regulatory changes precipitated in part by public fears about the possibility of massive releases of radioactivity rather than by changes based on the optimum safety-enhancing use of the latest technology. Thus, it will be important to assure a less prescriptive regulatory climate to avoid repeating this situation with advanced reactors.

STATUS AND PERCEPTION OF NUCLEAR DEVELOPMENT IN THE U.S.

The future of nuclear reactors for the production of electricity in the United States is uncertain because:

- There is no current market for nuclear reactors. No new reactors have been ordered since 1978. Utility surveys have indicated that there are no plans for building any new nuclear reactors in the foreseeable future.

- There is considerable public opinion to the effect that nuclear reactors are unsafe, unnecessary because of the availability of alternate sources for electrical generation, and too costly.

- Despite the passage of the Nuclear Waste Policy Act of 1982,

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many people still believe that there is no technical or institutional solution to the nuclear waste problem.

- Nuclear research and development in the U.S. has declined. R&D was formerly done by reactor manufacturers, the Electric Power Research Institute (EPRI), the Department of Energy (DOE), the Nuclear Regulatory Commission (NRC), and various universities. However, reactor manufacturers are no longer able to make significant investments since there is no market in the U.S. to warrant such investments. EPRI is maintaining a reasonable near-term R&D program, but DOE's nuclear reactor R&D program does not appear to have a strong goal-oriented direction. Also, the thrust of the NRC's advanced reactor-related work is unclear in light of changes in DOE's R&D programs and federal budget constraints. Moreover, the DOE's support of nuclear engineering research at universities is at a very low-level and is of great concern to the Subcommittee.

PURPOSE OF HEARING

The hearing was held to determine the nature of current and planned regulatory policies within the government, and particularly those of the Nuclear Regulatory Commission (NRC), which will affect advanced nuclear power plants. The implications of such policies for federal investment and private sector activities in the development of advanced reactor designs was also reviewed.

The Department of Energy is currently spending roughly $300 million annually (FY 86 appropriation level) for R&D associated with advanced reactor designs, including supporting research and technology. The greatest public benefit from this investment will be derived from such designs if the licensing policy for advanced reactors encourages enhanced safety, simplicity of design, standardization, reduced maintenance and lower costs.

OBJECTIVES OF HEARING

1) To determine what changes can be expected in the regulatory environment which will facilitate deployment of advanced nuclear reactors through a constructive licensing climate.

2) To review the public comments on NRC's proposed "Policy for the Regulation of Advanced Nuclear Power Plants."

3) To explore regulatory incentives which would encourage utilization of new materials and technologies to enhance reactor safety, performance, cost and useful life.

4) To explore the types of less prescriptive regulatory approaches which might be adopted for licensing advanced reactors.

5) To determine what directions R&D policy should take to foster advancements in reactor configuration, design and manufacturing which lend themselves to less prescriptive licensing approaches.

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6) To explore the interagency cooperation which could enhance the prospects of obtaining a return on the national investment in advanced reactor technology.

7) To discuss the type and source of funding and the lead times needed to assure significant benefits from advanced nuclear reactors.

FINDINGS

- The NRC does not have a definition of "advanced reactors." There was no clear definition of what constitutes an "advanced reactor". With no clear definition of what constitutes an "advanced reactor", there is little basis for confidence that an advanced reactor policy will result in significantly better reactors in the future. The definition should be tied to specific criteria. There was general agreement that an advanced reactor would differ significantly from current generation light water reactors. The majority of witnesses agreed that advanced reactors should provide a greater margin of safety prior to exceeding safety limits. There was also general agreement that advanced reactors should be more reliable as well as easier to construct. While there was general agreement on these points, no assurance was given to the subcommittee that the forthcoming advanced nuclear reactor policy would contain any firm definition. It will be difficult to obtain confidence in a policy if it leaves the door open for all reactors to qualify as "advanced."

- Performance criteria versus prescriptive criteria. It was stated by Dr. Kouts of the Brookhaven National Laboratory and Mr. Taylor of the Electric Power Research Institute that performance criteria have to be defined. As a minimum, the criteria should include: (1) the maximum allowable probability of a core disruptive accident; (2) the maximum allowable radiation dosages at the site boundaries; and (3) the minimum time period from when a transient condition is identified until operators would have to take corrective action to prevent core damage. The criteria should consider such parameters as the type and extent of acceptable reactor containment, the upper limits of reactor core power density, the "heat sink" (emergency thermal storage mass) capacity, the number and type of redundant systems and the length of time operators would have available to determine a proper course of action before implementing such action after an emergency is determined.

  However, the hearing also disclosed the need for providing adequate nuclear "codes and standards" in formulating an advanced nuclear reactor licensing policy. Prescriptive criteria, that is criteria which prescribe the kind and function of systems to be used in the design in order to achieve a certain level of safety, should be left to the reactor designer/manufacturer. Codes and standards, on the other hand, would provide the designer with the information on equipment and materials that the NRC accepts for use in nuclear power plants. These codes and standards, therefore, should be an integral part of the advanced nuclear reactor licensing policy, although not necessarily part of the policy statement, in order to

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establish a level of quality for reactor components.

- The Need for Enhanced Safety Criteria. In discussing whether or not advanced reactors should have greater safety margins than existing reactors, the majority of the witnesses agreed that a greater margin of safety was required. It was also pointed out that what is needed is a statement from the NRC which clearly specifies the levels of safety that must be met in order to obtain a license to construct a reactor under the advanced reactor licensing policy. Those criteria are needed now so that reactor designers and manufacturers know in advance what criteria they will have to meet. There was overwhelming concern that, in the absence of specific criteria, the NRC would endeavor to develop criteria as licensing progressed, adding to the expense of the project.

- The Need for Standardization of Nuclear Reactors. The NRC is developing and intends to issue a separate and distinct policy statement on standardization. Although there was concern expressed as to whether there should be a separate standardization policy, and if so, whether the advanced reactor policy also should contain standardization requirements, there was agreement among the witnesses that standardization is necessary. Statements were also made that the absence of standardization has partly been the fault of reactor manufacturers and architect engineers. While everyone agreed on the need for standardization, it was also clear that there are site location differences that have to be taken into account among future plants. There was also comment about each utility wanting to make design changes. Consequently, it would appear that standardization, if it is to occur, will require encouragement by the NRC through its policy. Again, any policy promulgated by the NRC should be clear, concise, and definitive in order to provide a firm basis for the design and manufacture of advanced nuclear reactors. It was not clear as to how evolutionary Advanced LWRs (i.e. the designs which GE and Westinghouse have cost-shared with the Japanese) should be treated in terms of standardization.

- Licensing policy. None of the non-government witnesses disagreed that many aspects of current NRC policies are relatively inflexible, complex, and duplicative. There was no disagreement that continually-changing NRC regulations cause undue delays which contribute to cost overruns in the design and construction of nuclear plants. The witnesses emphasized the need for an acceptable licensing climate. The majority of witnesses concluded that the current proposed advanced licensing policy provides no guidance on containment, single-failure modes, core power density, meltdown risks, or balance-of-plant standards. There was general agreement that a policy was needed and that the policy should commit the NRC to certifications and not leave the matter open to question as to whether a nuclear power plant built from a previously licensed advanced design is certifiable or not. There was discussion about ever-changing designs caused by changing sentiments within the NRC. Mention was also made of avoiding the use of Appendix A (General Design Criteria for Nuclear Power Plants) criteria for the licensing of advanced nuclear reactors. Finally, it was pointed out that economics and marketability should

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not be a part of the NRC's criteria or concern.

RECOMMENDATIONS

1. DEFINITION

Since there was no clear definition of what constitutes an "advanced reactor," the Subcommittee recommends that the NRC choose a definition based on the premise that the reactor should be significantly safer and more reliable than existing reactors as discussed by the majority of witnesses at the hearing.

2. PERFORMANCE CRITERIA

A. While the Subcommittee recognizes that the NRC may not always include specified levels of safety in its policy statements, the Subcommittee does believe that the nuclear industry has matured to the point where the NRC should be specific in its safety requirements, particularly when those requirements call for significant increase in the level of safety required. The Committee also believes that reactor manufacturers should have firm standards of performance to design to and not be subjected to constantly changing standards. Specific performance criteria were not offered in testimony during the hearing. However, the Subcommittee has endeavored to include such suggested performance criteria in this report which are illustrative of what it considers to be reasonable improvements.. These suggested criteria have been arrived at thru review of the record and consultation with industry representatives.

The Subcommittee recommends that the NRC specify appropriate safety performance criteria in its policy statement which includes measures such as: 1) a maximum probability of 1 in 100,000 of a significant release of radioactive material from a large scale fuel melt for a single reactor operating over a period of one year, 2) off-site radiation doses not to exceed 5 REM to the thyroid nor 1 REM whole body over a spectrum of accidents with a maximum frequency of 5×10^{-7} accidents per site year, and 3) that operators have at least 4 hours to prepare for corrective action after the initiation of an accident. Finally, the manner in which reactor manufacturers meet these performance standards, either by limiting core density, providing larger heat sinks, stronger containment, reactivity changes, or other means, should be left to the designers.

To supplement such performance criteria, the Subcommittee recommends the adaptation of realistic "codes and standards" as explained by Dr. Kouts during the hearing and as identified in the formerly stated Findings in this report. Such "codes and standards" should incorporate appropriate American Society for Testing Materials, American Society of Mechanical Engineers, and other professional codes whenever possible.

3. ENHANCED SAFETY

As stated by several witnesses, an advanced reactor, should be by

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definition, one that is safer than existing reactors. Probabilistic risk assessment was mentioned as a means to identify a level of safety and Chairman Palladino responded that it could be applied. Commissioner Bernthal stated "you clearly cannot stop with a baseline of 10 to the minus 4 for severe core damage accidents which is about where we are today."

Based on these discussions, the Subcommittee recommends safety levels such as those identified in Recommendation 2. Performance Criteria. The Subcommittee recognizes that reactor manufacturers may choose between licensing a present generation reactor, or evolutionary derivation thereof, or licensing an advanced reactor that would meet these minimum safety levels.

The manner in which these higher safety levels are achieved in accordance with published performance criteria, should be left to the designer/manufacturer provided that he can prove, through engineering analysis and/or by the testing of subsystems or a prototype reactor,* that his reactor qualifies as an "advanced reactor."

4. STANDARDIZED DESIGNS

The Subcommittee recommends that the NRC's Advanced Nuclear Reactor Policy include a firm requirement that each reactor manufacturer who submits a design for a license would do so on the basis that the submission would constitute a "standard design". However, any refinements necessitated by operating experience with the first reactor built to the advanced design and required to meet the performance criteria or to establish reasonable operating efficiency levels would be accepted as design changes within the context of "standardization". The construction of all new plants, ordered after the approval of the standard design and evaluation of its operation as a "prototype" for a reasonable time, would conform to the same plans and specifications.

The Committee expects, however, that the NRC's separate "standardization policy" will apply to the Advanced Nuclear Regulatory Policy except that, in any event, advanced nuclear reactors will qualify for certification of follow on units without relicensing except as may be required for site adaptation. Furthermore, it is expected that advanced reactors will be licensed on an expeditious basis because of their unique safety features.

* The Subcommittee recognizes that reactor prototypes may be slightly different than initial commercial units and expects that this difference will be incorporated in the licensing and certification process.

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SUMMARY

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General

The NRC's efforts to develop an advanced nuclear reactor policy began in November of 1983. After initial staff work and Commission review, the Commission published for comment a proposed policy for the regulation of advanced nuclear power plants on March 26, 1985. The Commission requested comments on several issues basic to the development of policy in this area. The public comment period has closed, and the Commission is considering revisions to the policy statement in light of these comments and staff recommendations.

Mr. Philip Bray, Senior Vice President of the Management Analysis Company, stated, "Administrative reform has been inadequate in bringing discipline. The passage of the current proposal for licensing and regulatory reform is the first necessary step in stabilizing the licensing process. This step is important for current design as well as the advanced reactor concepts." Mr. Bray went on to say, "Even modest demand projections call for shortages in the mid to late 1990's, and I do not believe the country can afford inaction on maintaining the nuclear option. Recently, last week, Edward Addison, President of Southern Company, one of the largest utilities, said, 'coal and nuclear energy are the mainstays we must count on through the remainder of this century and into the next. Unfortunately, we have boxed in both of these mainstays under a cloud of regulatory and legislative uncertainty.' I couldn't agree more." Further, Mr. Bray mentioned, "No utility executive in his right mind can buy a nuclear power plant, standard or advanced, today in spite of the continuing oil imports or increased purchase of electricity from Canada. You must ask yourself why. We have to have a disciplined approach as a form of encouragement to keep America on the threshold of technology in this very key industry." Dr. Herbert Kouts, Department of Nuclear Energy, Brookhaven National Laboratory, mentioned, "A trend is already clear toward nuclear power systems that will be simpler and more reliable, that will be based on acceptable solutions to some of the technical problems that now face existing reactors, that will be more obviously safe, and that will provide more certain protection against severe financial loss of the kind that occurred at Three Mile Island." Dr. Kouts said, "But the big job in altering the regulatory pattern to make it better suited to review an advanced reactor proposal will be enlarging on these safety goals and deriving from them an operational pool." Dr. Kouts continued, noting, "In the past year, the NRC had taken two steps that could have potential impact on future licensing. The first was the issuance of a proposed policy statement on severe

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reactor accidents regarding future designs and existing plants." As Dr. Kouts noted, this policy would tell the NRC how to conduct licensing reviews of nuclear plants in the future." The second was the issuance of a proposed policy for the regulation of advanced nuclear power plants." The notification identified an advanced reactors group that had been established in the Office of Nuclear Reactor Regulation for the purpose of preparing plans for the development of regulatory criteria for licensing proposed advanced reactors.

Mr. John Taylor, Vice President, Nuclear Power Division, Electric Power Research Institute (EPRI), believes that the NRC can adopt an effective policy to minimize complexity and provide stability and predictability in the licensing regulation of advanced reactors. He said, "In addition to setting forth the general design characteristics which contribute to more effective regulation, the policy statement should identify improvements in the regulatory process with the aim of achieving regulatory stabilization." To put the matter in perspective, Mr. Philip Bray said, "I was so disappointed when I saw a plant from General Electric purchased in 1969 or 1970 by Commonwealth Edison and just two years ago when it finished construction, it had 1100 design questions from NRC to get an operating license. This same design General Electric in 1970 sold to Japan called Fukishima VI. It has been running for six years and saved the Japanese people at least $2 billion in avoided oil import costs. This same design, this same supplier, manufacturer of equipment, mostly United States, what one went through a preapproval process and one went through a continuing design change process."

In response to one of Chairman Lloyd's questions, Mr. Bray added that for 25 years, the licensing system has functioned on the basis of a utility going to a supplier and indicating the desire to build a plant and actually purchasing the plant. Utilities then face the four year process of changing the design a thousand times in answer to NRC's questions. He noted that they have 27 amendments on an application. And then, they get a long letter from ACRS noting all the unresolved safety issues, and then at the bottom of the letter it is noted, they think this plant can be built without undue risk to the health and welfare of the public. Mr. Bray notes that that is the worst public relations that a billion dollar investment could have.

Definition of Advanced Reactors

The definition was discussed and rediscussed, but it was clear that there was no real quantifiable definition of an advanced reactor. It was equally clear that any type of reactor, including light water reactors (pressurized or boiling water), gas-cooled reactors, liquid metal reactors, and liquid metal fast breeder reactors, all could qualify as being an advanced reactor. In her opening statement, the Chairman of the Subcommittee on Energy Research and Production, Marilyn Lloyd, stated, "I guess you might ask first, what is an advanced reactor? I believe it is a reactor that has evolved from past reactor experience and from research, development and testing activities. I would hope that it is also a reactor that is better than previous reactors in terms of safety and reliability." Nunzio J. Palladino, Chairman, U.S. Nuclear Regulatory Commission (NRC) stated,

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"As a starting point, I would like to note that the Commission applies the term 'advanced' to those reactors that differ significantly from current generation light water reactors, or LWRs. We include reactors that provide greater margin prior to exceeding safety limits and/or utilize inherent, passive or other innovative means to accomplish this safety function. Advanced reactors of current interest include liquid metal-cooled reactors, or LMRs, high temperature gas-cooled reactors, or HTGRs, and advanced LWRs of innovative design, that is, those significantly different from the current generation of power reactors." James K. Asselstine, (NRC) Commissioner, noted, "If there is to be a future generation of nuclear power plants, and if the nuclear option is to be important or to be an important element of the nation's future energy mix, then we, the NRC, the reactor vendors, the utilities, and the Congress must ensure that the next generation of nuclear power plants is substantially better than the current generation." He went on to indicate that the next generation of plants must be more reliable, of more simplified design, easier to construct, easier to operate, and easier to maintain than the current generation. Then he stated, "Any design that does not accomplish this is not acceptable in my view."

Prescriptive Versus Performance Criteria

A. Safety Levels and Public Acceptance

In her opening statement, Chairman Lloyd stated, "It is incumbent that the NRC marshall its resources to establish realistic nuclear reactor performance standards in measurable terms which reactor manufacturers must meet or improve upon." She went on to question, "How can we assure ourselves that the attractive features of certain designs, such as passive safety, that will indeed enhance the degree of protection for the public and environment, that they will be recognized in the licensing process?" The Honorable Sid Morrison, Ranking Republican Member on the Subcommittee, asked, "How are you going to determine that advanced reactors provide the same degree of protection to the public as current LWRs, and will you use the same criteria that you have used in the past for making these evaluations?" Chairman Palladino reviewed the normal procedure, mentioning that the NRC reviews deterministic criteria, that they also make probabilistic risk assessments of the safety of the plant in order to identify accident scenarios that dominate in increasing the risk. But then he went on to say, "I should go on to add that I, for one, would like to see the advanced reactors aspire to higher goals and that is why I go along with saying I would expect them to do better than the baseline for the future." The Honorable Fred Bernthal, Commissioner, U.S. Nuclear Regulatory Commission, added the following, "Mr. Morrison, it is not very difficult really to see why we should require and why we need to require that the next generation and beyond reactors should develop a higher standard of safety. You don't need to get very far into debates and philosophical questions about incremental societal risks and risk compared to everything else. I think you can pretty well define the problem that faces the NRC in its responsibility for public health and safety, and the industry as well, quite frankly, by asking the question, how often one can expect a Three Mile Island-type event to occur and still have public acceptance of this technology. Commissioner Bernthal went on to say, "It seems to me in some remote

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future--that isn't today; we have about 100 reactors today--but in some remote future where you are approaching many hundreds of reactors perhaps to the point where you may even have the 1000 reactors we used to speak of in this country, you clearly cannot stop with a baseline of 10 to the minus 4 for severe core damage accidents which is about where we are today. That would imply, on average, a TMI type event every 10 years, and it is clear to me that the public simply wouldn't accept that."

B. Criteria Considerations

Commissioner Asselstine would like to see specific performance criteria in the area of containment and also in power density considerations. He quotes, "...those are the kinds of things or I think we could be more specific in providing overall objectives that would lead to a higher margin of safety from the design and still give the designers a great deal of flexibility of how they go about achieving that." The Subcommittee Chairman asked Commissioner Asselstine, "Do you think if we thought that the NRC should base future licensing policy on performance standards that require that all reactor operations under all conceivable conditions be within specified radioactive releases which remain below specified source term levels?" Commissioner Asselstine replied, "To the extent that can be done reliably, that is not a bad concept. I would say that I would like to see broad performance objectives. I don't think I want to tie it only to minimizing release levels from the plant. I think I would also want to avoid accident conditions, whether they result in releases or not, to maintain the approach of defense-in-depth that we have used in the past. But in terms of setting performance goals for the system in various parts of the system, I think yes, that is something we would like to consider." Chairman Palladino, commented, "I think performance objectives are very good criteria, and to some extent we use them now, but I think we could make better use of them. Our regulations have grown over the years based on the evolutionary nature of the designs, and I think your suggestion is one that we certainly should look more closely at for advanced reactors."

C. Codes and Standards

In his statement, Dr. Kouts mentioned, "What is really wanted as the basis for licensing review is a set of criteria at the level of performance specifications. These have to be structured to accommodate the variety of basic designs [of] advanced reactors that may be of interest. Below the present design criteria, and to some extent supplanting them, is a large body of codes, standards, guides and standard review plans used in assessing licensed applications, license amendments and operations. Over the years, these have generally assumed the character of prescriptive requirements. Sometimes they are interpretations of design criteria and sometimes they are additions to design criteria. In fact, most of these detailed criteria and requirements should really be used in the same way as code cases[1] in the normal engineering use of codes and

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[1]Referring to the use of professional society codes when applicable to specific systems.

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standards. Different code cases embodying different technical solutions may come to be acceptable ways of satisfying the same requirement. That is the way specific design solutions ought to appear in nuclear regulation."

Later in his statement, Dr. Kouts went on to mention, "In the eventual application of the results of the process of licensing of an advanced power reactor, the NRC will have to be on its guard not to slip back into licensing on a prescriptive basis. It is not easy to use performance standards, because sometimes their application seems to require an almost subjective judgment on whether the standard is met."

Mr. John Taylor, representing EPRI, concluded in his statement, "It is our judgment that these improved definitions can be less prescriptive for advanced reactor concepts incorporating a radical departure from current technology, more general guidance would seem appropriate initially to assure that unnecessary constraints are not placed on the development of new design concepts and, in the longer run, to accommodate major technical departures in such advanced designs."

D. Levels of Performance Criteria

Chairman Lloyd asked Mr. Vince Boyer, Chairman of the Management Committee, Gas Cooled Reactor Associates, the following question, "What...performance standards such as core melt or cooling and containment would you recommend that the NRC establish?" Mr. Boyer replied, "We believe these performance standards can be taken into account in the top level criteria which I have mentioned as well as the designation of the second level criteria. The safety goals address safety considerations and core melt considerations. Our top level criteria would designate doses and risks to the public from the total operation of the plant. We believe it is encompassed in these top level criteria. It doesn't have to be specifically addressed by areas such as you specifically identified." Mrs. Lloyd then asked, "You stated you thought it should be independent of reactor type." To this Mr. Boyer replied, "And it should be independent of reactor type, right. These top level criteria should be appropriate for any type of advanced reactor. The implementation may vary by the type of reactor, but that would be left to the design group." Dr. Kouts added, "I think that probabilistic risk assessment is going to have to be probably the most fundamental tool in assuring that we have non-prescriptive methodologies in licensing. All of the non-prescriptive methodologies will have to depend, to a large extent, on goals with respect to reliability, assurance of one kind or another. The way you have to determine that you have achieved conformity with the goals of this kind is some kind of analysis that leads you to estimates of probability of failure. So, we have to use this methodology regardless of what the error limits on the results will be."

Dr. Kouts explained the ability for assured shutdown as well as redundancy and diversity of safety systems is essential to reactor safety. Criteria can be built around things like this which can lead to remarkably low problem rates and you can construct sets of criteria which are non-prescriptive along lines of this kind.

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Enhanced Safety

A. Safer Reactors for the Future

In his statement, Chairman Palladino, mentioned, "...and indeed, advanced reactor designs which incorporate some or all of the characteristics outlined in the policy statement can be expected to exhibit greater margins of safety than current generation reactors. During the initial phase of advanced reactor development, the Commission particularly encourages design innovation which increase safety and reliability and which generally depend on technology which is either proven or can be demonstrated by a straightforward technology development program." Later, Chairman Palladino mentioned, "The Commission intends to require as a baseline the same degree of protection of the public and the environment that is required for current generation LWRs. But for the longer term, the Commission expects reactor designs to provide enhanced margins of safety." In his statement, Commissioner Asselstine mentioned, "However this policy statement comes out, I think the message should be that, first, future reactors should have a higher margin of safety than the current generation; second, the regulatory regime will be tailored to the demonstrated risk of the design; and, third, the Commission should encourage submittals of the PIUS and HTGR designs for staff review." As noted previously by Commissioner Bernthal, a TMI-type event every ten years will not be accepted by the public. Commissioner Asselstine added, "In fact one of the central issues that we have been arguing about this policy statement is whether we should say that advanced reactors should achieve a higher level of safety than the existing plants. Some on the Commission have been reluctant or unwilling to say that. There are words in various drafts about encouraging it and hoping that is what gets done. I don't see any reason why we couldn't or shouldn't say it." Commissioner Asselstine continued, "If we want something more than that, and if we want to see future improvements in the level of safety, now is the time to say so, while they are working on these designs, while they are spending money in the design effort. If we want more we are to say so now. Waiting down the road until getting a complete design and then saying, 'gee, this doesn't give us everything we want,' it seems to me, the wrong way to go. The vendors and the reactor manufacturers are in now saying, 'give us some guidance on what it is you want.' Now we ought to do that." He went on to add, "...one other aspect of the current prescriptive approach to requirements. If you had advanced reactor designs that offered substantially greater margins of safety because of the inherent safety features, the passive approach to safety that some of the advanced reactor manufacturers talk about, it seems to me that might justify a departure from the kinds of prescriptive safety requirements that we have had in the past. If you can show that just by the nature of the simplicity of the design that you provide a substantial additional measure of protection. That might well justify a fresh look at whether all of our current requirements really should apply in that kind of situation."

B. Foreign Nations and U.S. Seek Higher Safety Margins

The NRC's advanced nuclear reactor licensing initiative is consistent

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with activities in Great Britain and Japan. Commissioner Bernthal mentioned, "If I may make just a one minute additional comment, one other point that needs to be made is that we can't afford to be out of step with the rest of the world in this area. If you look at the extensive inquiry that is going on in Great Britain right now, the Sizewell inquiry, they are coming down on a severe core damage criterion that is about 10 to the minus 5, and that clearly represents an improvement over the current generation standard. I believe that Japan and other countries are moving in that direction, as well." Mr. Boyer added, "As you know, the U.S. HTGR program has established a modular HTGR as its reference design. One of the major perceived benefits of the modular HTGR is to capitalize on its inherent safety characteristics and thereby ease the current licensing demands and risks. Our objective is to establish an attractive nuclear alternative that attains comparable level of safety required for current light water reactors but in some more simple and demonstratable fashion."

C. Achieving Higher Levels of Safety

Dr. Kouts offered, "It is going to be very hard to reduce the error of limits below the kind of situation we have now, but we have to keep on with it. Error limits will only come down as we get more experience, because all of the error limits we have are the result of uncertainty with respect to failure limits on various things. With time, we know those failure limits better and better. We know the failure rates better and better and probabilities will become more sure. There are a number of principles which we have to come to realize more strongly in recent years that do contribute to reduce problems in reactors if you treat them right. One is assurance of an ultimate heat sink. If you can build into your system early the assurance of an ultimate heat sink, this certainly does tend in the direction Mr. Taylor talks about of reducing problems with the reactor. The assurance of electric power[2] has been one of the most important lessons that we have learned in water reactors, and this is certainly going to be carried over in other kinds of designs."

Standardization

A. The Advanced Reactor as an Operational Prototype

There was considerable discussion at the hearing concerning the standardization of nuclear reactors. There was also general agreement as to the need to standardize U.S. reactors in the same manner that other countries do in order to simplify licensing and to enhance performance. In his opening statement, however, Chairman Palladino stated, "Standardization will be the subject of a separate forthcoming Commission policy statement." While at first it may seem redundant to include standardization in the advanced reactor policy, there appears to be a valid reason for having a separate standardization policy since not all forthcoming reactors could expect to be advanced. In the Subcommittee's view, LWR's which are of evolutionary origin would not necessarily qualify as "advanced". Later in response to a

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[2]For the operation of pumps, motorized valves, and controls.

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question by Congressman Sid Morrison, Chairman Palladino responded, "Standardization should be something that we consider after we have at least had a prototype and have had some experience with a particular reactor. You don't standardize the first model, generally. However, I think with regard to our current generation of light water reactors, standardization is a goal we ought to really strive to achieve and certainly in the next generation of reactors." Chairman Palladino continued, "With regard to a standardized plant, we could by rulemaking settle a number of the issues and make that design available for replication over a given period of time." Commissioner Asselstine added, "I think you are absolutely right that we should at least make it clear up-front that it is that we are looking for. I agree with Chairman Palladino that for future plants that are similar to the current light water reactor technology, we ought to be able to standardize now, and I think really the Commission ought to insist on it unless there is a very good reason why someone needs to submit a custom plant application." Later Commissioner Asselstine noted that safety issues continue to be argued even when the plant is being built and even after the plant is complete, meaning that this adds extreme difficulties for the designers and manufacturers. Congressman Morrison stated, "Maybe we can all get together, maybe this new go-around of nuclear reactor designs will afford an excellent opportunity to improve our record." To that, Commissioner Asselstine replied, "Well, the utilities have been saying that, or some of the utilities have, that it is to their credit. I think there is less consensus on it among the reactor manufacturers and the architect engineers. I think maybe they are the ones who need to be brought along a little bit in terms of commiting standardized designs and getting the design work done before the initial construction approval for the plant."

B. Certification and Streamlining the Licensing Procedures

The "certification" of an advanced reactor was of interest to the non-government witnesses because this would expedite licensing of reactors after the full licensing of the first-of-a-kind. Chairman Lloyd questioned, "I really wanted to ask you this afternoon. Assuming that you encourage standard designs, and I think you are moving in that direction, is it your opinion that once we have a standardized design that has been licensed that these reactors that are designed, fabricated and constructed with the very same precise specifications and drawings, that they could be certified without the necessity of going through the same licensing review and approval, the same as with the initial application?" Chairman Palladino replied, "Madam Chairman, our intent is that standardized designs, and I would expect more than one but I hope not many, that these would not have to go through the same review...." Chairman Lloyd responded, "...but if they were the very same precise specifications?" Chairman Palladino answered, "There are site differences that would have to be addressed and the interaction of the plant with those site differences that would have to be addressed, but the designs would not have to be reviewed over and over again." Chairman Lloyd asked, "The site would be the only qualifying difference?" Chairman Palladino replied, "I think that would be the principal difference and maybe the only difference." Chairman Lloyd asked, "Have you put a plan into place for certifying these designs in this manner? What plans have you made

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for putting this into place?" Chairman Palladino replied, "You mean the standardization matter?" Mrs. Lloyd, "yes." Chairman Palladino: "We have under development or under direction to the staff to develop a standardization policy around which we can prescribe some of the concepts that we are discussing here." Commissioner Bernthal responded, "I would just make the comment, as I think you were indicating, Madam Chairwoman, one of the problems in our getting about the business of promulgating our standardization policy statement is to agree on a definition of a standard plant. I am not sure even that all of the Commissioners have the same idea at this point exactly what the standard plant means. The key issue, as you suggest, is the question of where the balance of plant begins and where you can have a really highly specified design that can be transplanted essentially in tact from one site to the next. That is an issue we still have to resolve and I know that some of the national laboratories have wrestled with in their review of some of the proposed standardized plant designs as well." Chairman Lloyd then called on Commissioner Asselstine who commented, "Madam Chairwoman, there is a balance here to be struck on standardization as to how far you go. Fred mentioned the nuclear portion of the plant as opposed to the balance of the plant. We need to decide how much of the plant design we want to see and how much we want to see standardized. We also need to decide how far in detail in terms of the specific design of the plant we need to go. One of the things the industry argues is if you go too far, then it limits their ability to obtain suppliers for the plant. For example, you can go so far on the design that the only way to meet the design is to order a particular component from a particular manufacturer." Mrs. Lloyd asked, "Isn't that what we are trying to get away from?" Mr. Asselstine answered, "Well, there needs to be some flexibility there on the part of the industry, but standardization is going to take discipline on both sides. An individual utility, once you have a standardized design, ought not then to try to change the design at will to make it fit exactly what they want unless there is a very good reason to do that. They are going to have to exercise some restraint when changing the design once we approve it, and we are going to have to exercise restraint in changing the design once we approve it so that you would really get the benefits of standardization." In his statement, Mr. Philip Bray explained, "For example, in Japan, there are standard nuclear powerplants based on U.S. technology. Standard nuclear plants are being built by many of the Japanese utilities. Japanese utilities are paying companies such as General Electric Company and Westinghouse Corporation for their contributions to the advanced pressurized water reactor and the advanced boiling water reactor which will first be used in Japan."

C. The Need to "Grandfather" Existing Reactors

Mr. Philip Bray explained, "For years I personally, as a member of the industry, have advocated that we institute a disciplined approach to plant licensing that would encourage the use of standardized plants. In essence, I am contradicting Commissioner Asselstine. The industry did push for standardization. At one time we introduced from General Electric a total standard plant design. We knew the utilities wanted it. We introduced in 1972, and it is after my retirement in 1985, and it is still not noticed as something that can be referenced by a

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utility without a fear of change. We are losing." Mr. Bray further commented about his experiences in introducing advanced reactor designs only to find that the NRC then wanted to "backfit" 15 other plants. Executives from these other plants then called Mr. Bray and criticized him for interfering with their license applications and construction programs. Congressman Sid Morrison questioned Mr. Vince Boyer, "I did want to start with a question for Mr. Boyer. Of course, we are very interested in what the Gas-Cooled Reactor Associates are putting together. Do you envision your modular unit as a standardized plant that could be produced in a factory?" Mr. Boyer responded, "Absolutely, yes. That is one of the objectives, to have a short construction time, to have modules that can be factory-fabricated to the extent possible to reduce the construction time thereby reducing the overall investment and the interest during the fabrication of the plant."

The Need for a Streamlined Advanced Nuclear Reactor Licensing Policy

A. Congressional Concerns

In her opening statement, Chairman Lloyd noted, "Clearly, it is not responsible for us to continue to encourage development of these advanced concepts without some assurances that an acceptable climate will exist and reasonable mechanisms will be in place for licensing these machines." Later in her statement, Chairman Lloyd noted, "We are very interested in how the Commission will go about its business in defining safety standards and the degree to which these standards will protect the public. We also must understand the extent to which these standards have been met and will be based on qualification testing of nuclear systems. Finally, we are interested in a certification mechanism whereby a standard design previously licensed can be replicated." Congressman Sid Morrison stated, "While it is difficult to measure, I believe that unyielding, complex, and duplicative NRC regulations are a cause of delays. These delays, with the accompanying cost overruns, have made nuclear power an unattractive option. If these types of regulatory delays carry over, several promising, innovative nuclear reactor technologies will never be translated to the drawing board to the marketplace." Chairman Palladino, in his statement, mentioned, "The Commission's primary objectives in proposing to issue an advanced reactor policy statement are three-fold: first, to encourage the earliest possible interaction of applications, vendors, and government agencies with the NRC; second, to provide all interested parties, including the public, with the Commission's views concerning the desired characteristics of the advanced reactor design; third, to express the Commission's interest to issue timely comment on the implications of such designs for safety and the regulatory process." Later in his testimony, Chairman Palladino said, "The Commission intends to issue, in the near future, a safety goal policy statement to provide further guidance regarding safety objectives." He went on to say, "Regulatory guidance for such reactors could encourage those characteristics that have the potential for fostering a simplified regulatory framework and enhance safety while remaining sufficiently general so as to avoid placing unnecessary constraints on the development of new design concepts."

B. NRC Concerns

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Commissioner Asselstine noted, "The advanced reactor policy statement provides no guidance on what containment capabilities will be required; on whether the single failure criterion is adequate for the future; on acceptable core power densities, an issue which has a significant bearing on the core meltdown risk to the public; and on the root causes of the core meltdown risks that might be designed out of the future generation of reactors. Nor is there guidance on what standards the balance of plant must meet." Later he noted, "Yet this advanced reactor policy statement would accept the next generation of U.S. nuclear powerplants if such a design provides a level of safety equivalent to that achieved in the U.S. designs that were completed over ten years ago." The Commissioner made an additional comment, "I find it disappointing that the NRC cannot generate a set of safety requirements for the next generation of plants." Commissioner Asselstine further stated, "They (the public) deserve to know from a hard-eyed, independent, authoritative source whether the safety claims often made for reactor systems have merit and whether they truly offer significant improvements over the current generation of reactors." He went on to say, "It is my opinion that when it comes to plant designs, we at the NRC should long have and certainly now ought to look at almost everything that comes our way and give each legitimate new reactor concept an appropriate evaluation." Chairman Lloyd asked Chairman Palladino about minimizing the complexity and eliminating the uncertainties in the licensing process. policies in the NRC which I don't want to see happen." Chairman Palladino replied, "Madam Chairwoman, I believe that the major gain will be made by our interaction with the designers early in the process so that we can resolve major issues and understand the issues and identify the issues early on so they can be given attention." Later, Chairman Palladino mentioned, "I would expect that the performance specifications would be an important aspect of the future criteria." Later, in response to a question from Congressman Morrison, Chairman Palladino added, "Mr. Morrison, we have not finalized when this policy will get out. I would hope that we don't take too long at it. I find it difficult to speculate when the Commission will finally reach a conclusion on any particular policy, but I certainly would hope that it will be done this winter, if not before." Chairman Lloyd called on Commissioner Bernthal saying, "One of the concerns that has been raised is that since the Advanced Reactor Groups is rather small and the possibility does exist that the advanced LWR designs might be reviewed by a separate and larger group. I just wanted to get your opinion on what provisions there could be in your organization to make sure that we had serious and timely reviews of other designs besides the advanced LWRs. There is a concern that that is going to be the number one game in town." Commissioner Bernthal responded, "I don't think there is any question that the primary task before the Commission presently is to evaluate and carry forward on those standardized plant designs that are currently in process of development within the industry. Some of them are in various stages, are still evolving standardization process within the NRC. The initial elements of that process, incidentally, were defined in the severe accident policy statement that the Commission issued not so long ago. I don't see any serious difficulty in principle with the fact that design appraisal effort will be carried out within one group and it will be another small group that will look at the more speculative, futuristic, if you will, designs

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that will come after the next generation of powerplants. But I do want to make clear that in my judgment, the elements that we set forth in this advanced reactor policy statement should apply to all reactors, the next generation of standardized plants as well as the more advanced reactors beyond that." Commissioner Bernthal continued, "Now the details of exactly what the Commission's safety goal is, getting back to the previous point, we are also going to address very shortly in the Commission's safety goal policy statement. So, the short answer to your question is, I don't necessarily see any organizational problem in separating those evaluative functions of the so-called immediate next generation LWR plants. I am quite confident that Mr. Denton and others in our agency have the management capability to toss them from one place to the other when that is required." Commissioner Asselstine added, "I think there is a potential risk that, because the advanced LWRs are perhaps farther along in the process, more attention might get paid to those and others might get the attention that the[y] need. I think we need to do both, due to the extent there is any uncertainty about that, the Commission ought to make it clear to the staff that for the more advanced concepts, HTGRs, PIUS-kinds of concepts, others, the Canadian concept that Fred mentioned, that we would like to see reviews done of those as well."

C. More Effective Licensing Criteria

Commissioner Asselstine said, "If someone comes in with a design which, because of its inherent and passive safety, does not require large numbers of duplicate safety systems or does not require the kinds of performance in quality assurance requirements that we have traditionally imposed in the past, we ought to consider whether we can relax those requirements and reward a design that, because of its inherent features, provides much greater margins of safety. That is one of the things I think we ought to be doing, particularly in looking for these different concepts." Mr. Boyer added, "The NRC should agree to identify a set of top level regulatory criteria which could be used to guide the evolution of advanced reactor designs. These criteria should be a necessary and sufficient set of direct statements of acceptable health and safety consequences or risks to individuals or the public, they should be independent of reactor type and site, and, to the extent possible, they should be quantifiable. Two, the NRC should agree to consider appropriate design-specific lower level criteria, the second level criteria, from these top level criteria which logically account for the unique safety and technical characteristics of the different advanced reactor concepts. Three, the NRC should commit staff resources to review these proposed methods and the evolving advanced reactor designs well in advance of a formal application for a construction permit." Mr. Boyer continued "The first two of these points must be addressed to provide assurance that advanced reactors will not be prescriptively regulated by requirements derived from current light water designs which the NRC might have in mind. It should be recognized that in the Code of Federal Regulations, many requirements and guidelines exist which are unique to current light water reactor design. It is necessary to distinguish which criteria are generic and which criteria are unique to a given reactor concept. Our third point relative to staff resources is that it is necessary to have the NRC cognizant, at an early stage, of the

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differences between the HTGR and other advanced reactor designs and current light water reactors. This will ensure that the lead time is available to establish a new set of criteria for advanced reactors before the pressures of an application for a construction permit." Mr. Boyer went on to inform the Committee that the U.S. HTGR program had submitted a listing of proposed top level regulatory criteria. He noted that a document was submitted to the NRC in June of this year. That document is included in the appendix of this report. Mr. Boyer went on to emphasize his second point by saying, "Our second point was that there is a need for the identification of a logical approach for going from a generic set of public health and safety criteria to design-specific criteria. Here we believe that the current policy is vague. For example, the policy states, 'the Commission intends to make use of existing regulations where such regulations are applicable to advanced reactors and where their use would be practical.' The policy, however, never really defines what is meant by the word 'practical.'" Later Mr. Boyer added, "However, we believe it is important to get on with the job and define the specifics." Later Mr. Boyer went on to discuss the fact that after analysis and separate effects tests are completed, there may still be uncertainties that dictate extra conservatism and the cost of designing and building a fully prototypical demonstration might be required. In his testimony, Mr. Philip Bray added, "We must have a philosophy of approval, sign-off, acceptance, certification, not terms such as we have been using, for later review, unresolved safety issues, preliminary approval. Unless utilities see meaningful sign-offs, they cannot meet their fiduciary responsibility if they buy a plan whose design is ever changing. In fact, unless the process of sign-off exists, designers and manufacturers, U.S. or international, cannot and will not make the significant investments for technological advancements to lead to the advanced reactor designs."

D. A Licensing Analogy - Airworthiness Certifications

Mr. Bray added, "For many years, I personally have advocated the concept of a power worthiness certificate. Congress was effective in passing a similar law with the FAA. Why not do it again and do your part in endorsing a prudent acceptance of nuclear power here in the U.S.? Japan does it. France does it." Mr. Bray went on to describe the similarities between the licensing of aircraft and the licensing of nuclear reactors, pointing out that they were both highly technical, that they both impacted the safety of the public, and that they were consistently advanced from time to time. He was correct in explaining how the FAA licensing system benefited the technology while the NRC system did not benefit the use of nuclear energy. Mr. Bray said, "The recent certification of the Boeing 767 aircraft, a truly advanced design, was totally disciplined. As far as I know, the certification had no adverse impact on the fabrication or operation of earlier designs such as the 747. Each had an independent certification process. Under such a certification process, I am confident there would be less of a trauma for a utility to consider the purchase of a certified design, either one with current or one with advanced nuclear reactor technology incorporated in it. I am also confident that we would have return an economic incentive to system suppliers, either U.S. or international, to bring their technology to the U.S. marketplace."

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E. The Inappropriate Use of Appendix A Criteria

Dr. Herbert Kouts from the Brookhaven National Laboratory went on to define the licensing process after the establishment of safety goals. He said, "The next stage down from the safety goals is criteria to be used in guiding designs and design review. Criteria of this form have been developed for today's water reactors and have been used before then for two decades. They are given in Appendix A of Title 10, part 50, of the Code of Federal Regulations. These criteria were first generated in the early 1960's during the formative period of the present nuclear industry. They were important in structuring the safety features of the plants that now exist. They have undergone some change since then, but by and large they are the same as they were twenty years ago. During the period when plans were progressing for a commercial fast breeder in this country, attempts were made to apply the Appendix A criteria to breeders also. The results were uneven and, in many respects, unsatisfactory, because the criteria were written with water reactors in mind, and many of the criteria refers specifically to features present only in water reactors. It is clear that the Appendix A criteria are not suited to use in connection with breeders or other types of fast reactors. Yet something corresponding to them is necessary and will have to be developed. The Appendix A criteria have another problem, too. They are not uniform in concept. Some of them have the appearance of performance specifications, but many of them are very prescriptive, very specific. What is really as the basis for license review is a set of criteria at the level of performance specification. These have to be structured to accommodate the variety of basic designs of advanced reactors that may be of interest."

F. Public Acceptance

Chairman Lloyd questioned Mr. Vince Boyer, asking, "Looking at future licensing policy, do you think it is reasonable to expect that a well-designed nuclear plant would meet all of the performance safety criteria regardless of the design of the rest of the plant outside of the nuclear steam supply system?" To that, Mr. Boyer replied, "You are referring to the balance of plant section?" Mrs. Lloyd replied, "yes." Mr. Boyer answered, "I believe that the regulations should apply to the nuclear steam supply system. However, the balance of plant should not be overlooked, because I believe it can be accommodated by the designer and by the purchaser. In the HTGR case, our top level goals have set criteria for maintaining safe plant operation and for maintaining reliable plant operation. In these subsets of these goals, we have set normal plant outage percentages of 10% for forced outages and our design will work toward meeting those criteria which means that we have to look at the balance of plant as well." Chairman Lloyd asked Mr. John Taylor, "I think it is pretty well taken now that the public is rather skeptical of the safety of nuclear power. How do you think a streamlined reactor licensing policy could be presented so as to convince the public, the Congress, and the nuclear industry that all of our concerns can be reconciled in a common approach?" Mr. Taylor responded, "That is the toughest question I have had in a long time. The fact that the entire system

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will be examined in quantitative measures, as Chairman Palladino mentioned this afternoon, more recently developed can be applied with reasonable confidence to an estimated risk, and the fact that the risk can be shown on a quantitative dependable basis to be substantially lower that even those of us in the industry thought possible just a few years ago before Three Mile Island occurred, I think will be the major reason that the public will begin to accept nuclear power as safe as we think it is today." Mr. Bray added, "I think public acceptance will go up as these bills that are before the Congress now recognize the certification aspect and that the suppliers say it's worth investing the $300 million or $400 million to come up with all the answers, without a sale, so that the government can say this design is certified. If a utility buys it, and it is monitored by the NRC, and they build it this way, it can load fuel and go to power."

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WITNESSES

October 31, 1985:

Hon. Nunzio J. Palladino, Chairman, U. S. Nuclear Regulatory Commission
Hon. James K. Asselstine, Commissioner, U. S. Nuclear Regualtory Commission
Hon. Lando W. Zech, Commissioner, U. S. Nuclear Regulatory Commission
Vincent S. Boyer, Chairman, Management Committee, Gas-Cooled Reactor Associates
Philip Bray, Executive Vice President, Management Analysis Co.
Dr. Herbert J. Kouts, Chairman, Department of Nuclear Energy, Brookhaven National Laboratory
John J. Taylor, Vice President, Nuclear Power Division, Electric Power Research Institute

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